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INVESTIGATION OF THE DUST CONTENT OF THE ATMOSPHERE

By HERBERT H. KIMBALL and IRVING F. HAND

SYNOPSIS

This paper summarizes determinations of the dust content of the atmosphere made at the American University, D. C., with an Owens dust counter. Variations with the seasons and with the direction and velocity of the wind are shown, and are attributed principally to smoke from the near-by city of Washington. A close relation is shown between the limit of horizontal visibility and the dustiness of the atmosphere.

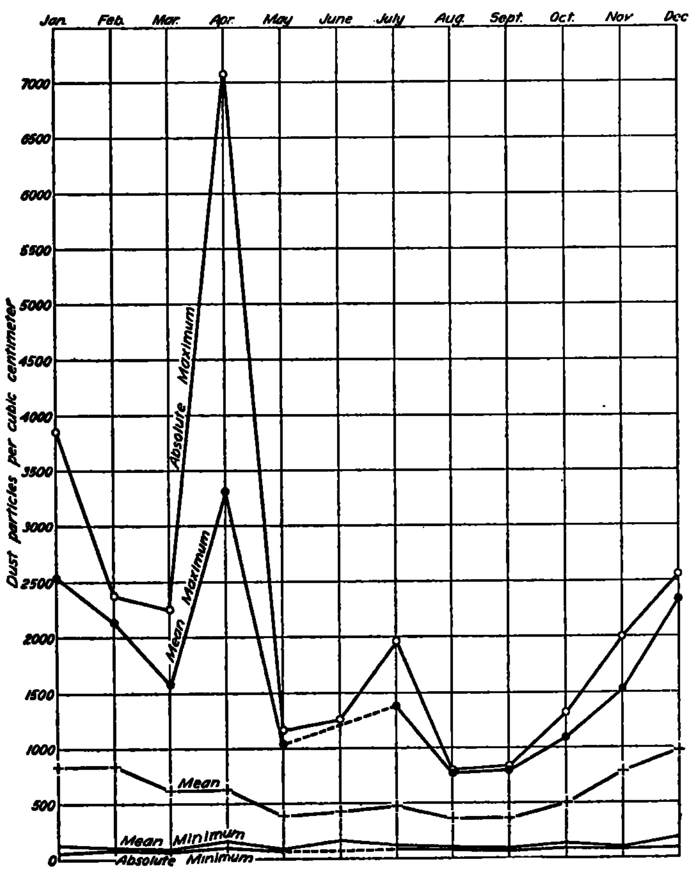

FIG. 1.—Monthly means and extremes of the dust content of the atmosphere at the American University, D. C.

Determinations made during free-balloon flights show considerably less dust than was found during previous airplane flights.

Spores were observed at intervals in 1924 between July 12 and November 21. They were first observed in 1925 on June 8.

INTRODUCTION

The results here summarized are in continuation of those published in the MONTHLY WEATHER REVIEW for March, 1924, 52:133–141. The Owens dust counter, shown in Figure 1 of that paper, has been used to deposit the dust from a known volume of air on a microscope cover glass. The dust thus deposited has been examined and counted by means of a high-power microscope in the manner described in the same paper.

Unless otherwise stated, all dust determinations have been made at the American University, which is northwest of the city of Washington at a distance of about 2 miles from the section known as Georgetown, 4 miles from the White House, 5½ miles from the Capitol, and 5 miles or more from all important railroads. The tabulated summaries that follow include observations made at 8 a.m. only.

Seasonal variations.—In Table 1 are given the monthly means, the monthly maxima, and the monthly minima of dust determinations from the beginning of observations in December, 1922, to April, 1925, inclusive. The monthly averages and extremes are also shown graphically in Figure 1. Aside from the marked increase in dustiness during the winter season, there are considerable variations in monthly values from year to year, and especially in the maxima. These variations are undoubtedly due principally to local smoke from the city, and they will probably increase in magnitude, as building operations are rapidly extending the residence section to the north and south of the university.

TABLE 1.—*Dust content of the atmosphere at the American University, D. C., at 8 a. m. (dust particles per cubic centimeter)*

MONTHLY MEANS

Year	January	February	March	April	May	June	July	August	September	October	November	December
1922												1,208
1923	1,061	905	540	476	393	----	397	388	386	395	451	557
1924	719	533	409	645	376	420	539	326	335	598	1,110	1,159
1925	723	1,092	909	753								
Means	834	843	619	625	384	420	468	357	360	496	780	975

MAXIMUM

Year	January	February	March	April	May	June	July	August	September	October	November	December
1922												2,088
1923	3,860	2,050	1,155	1,182	905	----	793	794	812	853	1,023	2,340
1924	2,403	1,984	1,280	1,661	1,154	1,250	1,953	796	823	1,306	1,987	2,551
1925	1,352	2,370	2,247	7,077								
Means	2,538	2,128	1,561	3,304	1,030	1,250	1,373	795	818	1,080	1,505	2,326
Extremes	3,860	2,370	2,247	7,077	1,154	----	1,953	796	823	1,306	1,987	2,551

MINIMUM

Year	January	February	March	April	May	June	July	August	September	October	November	December
1922												298
1923	214	105	113	113	65	----	90	110	59	96	71	90
1924	124	97	76	151	124	155	124	87	97	155	113	124
1925	57	77	87	202								
Means	132	93	92	155	94	155	107	98	78	126	92	171
Extremes	57	77	76	113	65	----	90	87	59	96	71	90

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The remarkably high maximum of 7,077 in April was obtained at 8 a. m. on April 7, 1925. A smoke cloud that in the absence of wind had collected over the city in the early morning was lifted by convection and carried by a light easterly wind over the university. By noon the sky had cleared, and the dust content was only 166 particles per cubic centimeter, or less than the minimum for the month at 8 a. m., and the visibility had increased from three-fourths to 30 miles.[1] The July maximum of 1,953 was obtained on July 21, 1924, a day with dense haze.

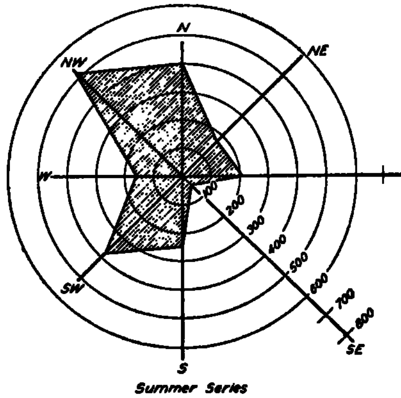

FIG. 2.—Variation in the dust content of the atmosphere with wind direction during the warm months (April to November). Note: The average dust content (particles per c. c.) with each wind direction is indicated by the length of the straight line drawn for that direction. The shaded area at the center of the figure indicates the relative frequency of winds from the different directions

Variation with wind direction.—Figures 2 and 3 show the variations in the dust content of the atmosphere with wind direction in the warm (April–November) and the cold (December–March) months, respectively. The preponderance of dust when the wind is from an easterly direction undoubtedly is due to city influence. The secondary winter maximum with west winds may be due to smoke from the heating plant of the nitrate fixation laboratory, which is about 600 feet west of the college of history building where the dust records are obtained. In winter the minimum dust content is found with northwest winds; in summer, with west to north winds.

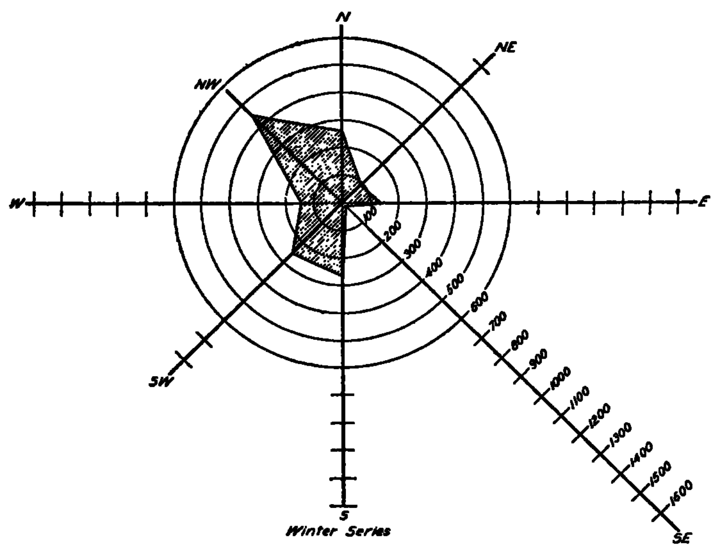

FIG. 3.—Variation in the dust content of the atmosphere with wind direction during the cold months (December–March). Note: The average dust content (particles per c. c.) with each wind direction is indicated by the length of the straight line drawn for that direction. The shaded area at the center of the figure indicates the relative frequency of winds from the different directions

[1] See Hand, Irving F. Effect of local smoke on visibility and solar radiation intensities. This REVIEW, April, 1925, 53: 147–148.

TABLE 2.—*Summary of atmospheric dust counts, American University, 8 a. m.*

GROUP A. WINTER MONTHS—JANUARY TO MARCH, 1924; DECEMBER, 1924, TO MARCH, 1925

Number of observations	N per c. c.	Humidity		Wind		Visibility
		R. H.	e	Dir.	Vel.	
		Per cent	*Mm.*		*M. p. h.*	*Miles*
2	68	58	2.36	NW	14	68
7	110	59	3.53	NW	14	50
13	221	63	3.62	NW	9	30
10	428	60	2.81	NW	8	30
18	317	61	1.96	NW. and N	9	20
5	498	66	2.33	NW	6	20
5	705	64	2.36	N	8	12
3	600	60	2.46	N	4	10
15	381	70	3.37	N	7	5
26	748	68	3.45	NW	5.2	5
20	1,495	75	3.80	NW	5	5
10	641	83	3.60	NE	7	3
16	1,744	77	4.78	S	4	3
1	865	68	2.62	E	8	2
9	1,640	83	4.43		4	1

GROUP B. SUMMER MONTHS—APRIL TO NOVEMBER, 1924, AND APRIL, 1925

Number of observations	N per c. c.	R. H.	e	Dir.	Vel.	Visibility
3	114	59	7.47	NW	11	68
6	146	63	7.09	NW	8	50
4	224	73	5.88	W	4	50
16	169	71	11.01	SW. and NW	7	30
17	345	63	8.50	NW	7	30
15	263	68	11.45	SW	5	20
11	592	64	6.60	N	8	20
13	347	73	14.07	SW	3	12
8	625	69	7.31	NW	4	10
34	403	77	11.52	S	4.5	5
33	745	66	8.94	SW. and NW	5.5	5
7	1,214	73	6.82	NW	6	5
21	535	82	12.52	NE	6	3
16	1,453	77	7.58	NE	4	3
3	742	96	9.20	NW. and N	2.5	[1] 1
1	1,180	83	9.47	SW	2	1
1	7,077	83	4.75	E	1	¾

[1] Light fog.

CORRELATION OF ATMOSPHERIC DUSTINESS WITH VISIBILITY

In Table 2 the dust measurements made between January, 1924, and April, 1925, inclusive, have been summarized in two groups. Group A includes the data for the cold months, December to March, inclusive, and Group B the data for the warm months, April to November, inclusive. Subdivisions in these two groups are arranged in accordance with the limit of visibility. In general, except with a visibility of 50 miles or more, the number of dust particles corresponding to a given visibility is slightly greater in winter than in summer. In both the warm and the cold periods increased dustiness is accompanied by decreased visibility.

Table 2 also shows that during the cold months decreased wind velocity is usually accompanied by increased atmospheric dustiness. While there is the same general tendency in the warm months, Table 3 and Figure 4 show a rather marked departure from the rule with winds of 8 to 9 miles per hour. Only 10 observations are available with winds of 9 miles. One of these was with a northeast wind and a dust content of 553 particles per cubic centimeter; four with an east wind and an average dust content of 482; the other five with northwest wind and an average dust content of 892. On one of these latter "Dense haze and smoke" was recorded and on another "haze on the horizon." It may be that winds of this velocity at 8 a. m. in summer are indicative of sufficient wind movement during the day to introduce considerable surface dust into the atmosphere, while at Washington winds of higher velocity usually follow rainstorms that have washed out the dust from the atmosphere and left the ground surface moist.

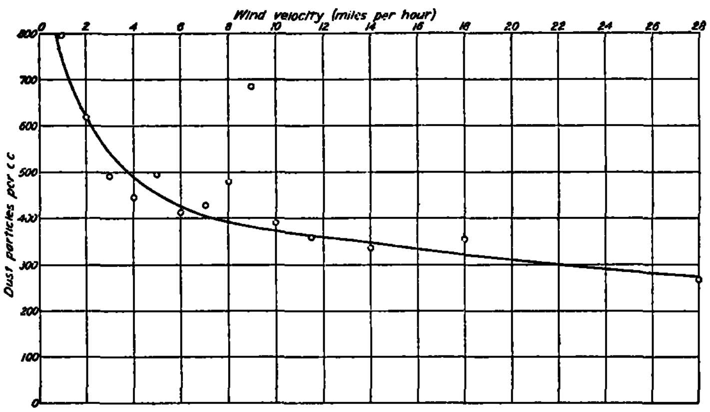

FIG. 4.—The relation between wind velocity and the dust content of the atmosphere during the warm months (April to November)

TABLE 3.—*Relation between wind velocity and dust content of the atmosphere in the warm months (April–November)*

Wind velocity, miles per hour	1	2	3	4	5	6	7	8	9	10	11–12	13–15	16–20	28
Number of occurrences	39	53	44	50	25	49	10	31	10	22	31	11	5	1
Number of particles per cubic centimeter	796	619	481	444	496	412	427	476	684	390	358	335	333	269

The relation between dustiness and visibility is clearly shown in Table 4, which summarizes all observations made at 8 a. m. between December, 1922, and April, 1925, inclusive.

In the equation,

$C = N \times R.\,H. \times D,$

N = the number of dust particles per cubic centimeter.

R. H. = the relative humidity as determined at the Central Office of the Weather Bureau at 8 a. m., and

D = the limit of visibility in miles.

In the paper already quoted above the value of C was given as 480,000. The mean value for Table 4 is only 390,000; or, if we omit days having a visibility of 10 miles or less, the mean value is 435,000.

TABLE 4.—*Values of* $C = N \times R.\,H. \times D$

Number of observations	D, visibility	C
	Miles	
5	68	362,800
33	50	408,200
78	30	528,150
44	20	484,600
17	16	415,700
18	12	407,700
53	10	338,700
212	5	263,900
90	3	246,300
1	3/4	440,500
Mean		390,000
Mean, excluding values for D=10 or less		435,000

The maximum value of C is for a distance of 30 miles. This is probably due to the fact that Sugar Loaf Mountain, an isolated peak, is at that distance from the university in a northwesterly direction. It is therefore not only a conspicuous object, but it is in a favorable direction for observing during the morning. The peaks in the Blue Ridge Mountains 68 miles west of the university are so little higher than other mountain ranges in the same direction that they can be identified only when the background as well as the intervening atmosphere is favorable. Objects visible at 10 to 20 miles are ranges of hills without marked characteristics. The towers of the Arlington Radio Station, at a distance of 5 miles, are conspicuous, but the intervening valley of the Potomac is apt to be smoky in the early morning.

On April 7, 1925, the visibility was carefully determined as three-fourths mile. This value, with the dust content, N, of 7,077, and a relative humidity of 83, gives for C the value of 440,500. On this date the dust was due principally to smoke, and the particles were larger than the average. Undoubtedly this is generally true when the visibility is less than 20 miles, as in such cases local smoke often plays an important part.

No doubt the size of the dust particles is generally a factor in determining the limits of visibility. For example, in October, 1924, the Blue Ridge Mountains at a distance of 50 miles were seen four times, with an average atmospheric dust content of 224 and an average relative humidity of 73, giving a mean value for C of 817,600. This was one of the driest months Washington has ever experienced, and the haziness of the atmosphere was pronounced. The dust particles were below the average in size. On the remaining six days during the warm months of 1924–25 on which a visibility of 50 miles was recorded, a mean dust content of 146 and an average relative humidity of 63 give for the value of C 459,900. On July 21, 1924 a day with dense haze, a dust content of 1,953, a relative humidity of 82, and a visibility of 3 miles give for the value of C 470,400. On July 12, 1924, at 8 a. m., the time of observation, a fire was in progress at the Benning stockyards, about 8 miles southeast of the university. The wind was 6 miles per hour from the south. A dust content of 1,659, a relative humidity of 93, and a visibility of 3 miles, give for the value of C, 465,000.

Diurnal variation in atmospheric dustiness.—On international days, as designated by the International Committee for the Exploration of the High Atmosphere, dust determinations are made at noon as well as at 8 a. m.

Between February, 1923, and April, 1925, observations on 16 days during the cold months, December to March, inclusive, give for the 8 a. m. mean 819 dust particles per cubic centimeter and for the corresponding noon mean, 627. During the same period observations on 40 days during the warm months, April to November, inclusive, give for the 8 a. m. mean 641, and for the corresponding noon mean, 414. For the entire period the 56 noon determinations show only 69 per cent as many dust particles per cubic centimeter as the 8 a. m. determinations. This is probably the result of the clearing of the atmosphere of local dust and smoke by the increase of wind velocity during the forenoon.

OBSERVATIONS FROM BALLOONS

During April and May, 1924, determinations of the dust content of the atmosphere were made by Dr. C. LeRoy Meisinger in connection with balloon flights from Scott Field, Ill. On account of the regrettable accident that led to the death of Doctor Meisinger on his last flight we have not been able to interpret his brief notes as fully as would have been the case had it been possible to consult with him in regard to them. The dust counter used by Mr. Hand during airplane flights in 1923 was employed, and the cover glasses were examined and the dust counts made by Mr. Hand after their receipt in Washington.

TABLE 5.—*Determinations of the dust content of the atmosphere during balloon flights*

FREE-BALLOON DETERMINATIONS

Date	Time	Location	Height above ground	Dust content, particles per c. c.	Remarks
1924			*Feet*		
Apr. 1	4:45 p. m.	Scott Field	0	798	
	5:35 p. m.	Near Scott Field	1,050	(1)	
	6:25 p. m.		1,900	101	
	6:52 p. m.	Over Nashville, Ill	3,000	38	
	8:00 p. m.	Over Mt. Vernon, Ill	4,000	28	Large particles like spores.
	8:50 p. m.	Over Wayne City, Ill	5,100	(1)	
	9:06 p. m.	Over Mill Shoals, Ill	5,950	16	
	9:39 p. m.		7,000	9	
2	12:30 p. m.	Over Augusta, Ga	6,800	16	
	1:30 p. m.		6,000	(1)	
	1:50 p. m.		5,000	19	
	2:25 p. m.	Waltersboro, S. C	4,000	22	
11	3:45 p. m.	Near St. Jacob, Ill	2,600	36	
12	7:00 a. m.	Near Wasepi, Mich	2,000	41	
	9:05 a. m.	Over Jackson, Mich	4,000	59	
	11:10 a. m.	4 miles W. Detroit	3,500	57	
	11:40 a. m.	Over Detroit, Mich	1,000	152	
	12:35 p. m.	Over St. Claire Lake	4,100	23	
18	7:50 p. m.	4 miles NNE. Mascoutah, Ill	1,300	69	
	8:05 p. m.		2,500	24	
	8:35 p. m.		3,700	13	
	9:15 p. m.	SW. Mt. Vernon, Ill	4,800	38	
23	6:10 p. m.	E. Wanda, Ill	1,500	76	
24	6:40 a. m.	Over Lake Michigan	1,500	71	
	1:45 p. m.	3 miles SE. Black Creek	1,800	55	
29	3:20 p. m.	2 miles NNE. Lebanon, Ill	3,000	44	
	3:40 p. m.	4 miles SSE. Troy, Ill	4,100	40	
May 7	5:14 p. m.	4 miles SE. Scott Field	2,200	69	
	5:25 p. m.	1 mile S. Mascoutah, Ill	3,000	48	
	5:52 p. m.	Above clouds	4,300	16	
	6:14 p. m.	Above clouds	5,200		Cover glass broken.
	6:40 p. m.	Above clouds	6,200	12	
	7:00 p. m.	Above clouds	6,800	(2)	
DIRIGIBLE DETERMINATIONS					
Apr. 28	10:00 a. m.	1 mile W. Scott Field	600	35	
		2 miles NE. Belleville, Ill	550	95	
		2 miles W. Belleville, Ill	550	72	
	to	1 mile S. Country Club	600	117	
		5 miles W. East St. Louis	600	108	
		5 miles W. Free Bridge	500	60	
		2 miles W. Free Bridge	500	44	
	11:00 a. m.	3 miles W. Belleville	500	38	
	11:45 a. m.	2 miles W. hangar	400	76	
	Noon	1 mile SW. hangar	300	98	
SCOTT FIELD DETERMINATIONS					
Mar. 31	3:45 p. m.	Scott Field	0	522	
Apr. 7	2:00 p. m.	Scott Field	0	142	
8	10:00 a. m.	Scott Field	0	303	White sky.
9	9:30 a. m.	Scott Field	0	112	
10	11:30 a. m.	Scott Field	0	192	

[1] No visible record. [2] Less than 10.

Table 5 gives the time, place, and height above ground at which dust determinations were made. Table 6 summarizes the results.

TABLE 6.—*Summary of atmospheric dust determinations from balloons*

Height in feet	Number of determinations	Dust particles per c.c.			Remarks
		Mean	Max.	Min.	
Between 5,950 and 7,000	5	13	16	9	Free balloon.
Between 3,700 and 5,000	9	29	59	13	Do.
Between 2,000 and 3,500	8	45	69	24	Do.
Between 1,300 and 1,900	5	74	101	55	Do.
1,000	1	152			Free balloon over Detroit.
Between 300 and 600	10	74	117	35	Dirigible balloon.
Surface	6	345	798	112	At Scott Field.

These determinations show considerably less dust in the atmosphere than was found by Mr. Hand during airplane flights. This is partly explained by the fact that the balloon flights were made in the spring when we would expect less dust in the atmosphere than late in the season after convection has been adding to the dust at high levels for a long period. Further, it was suspected that some of the dust found during airplane flights came from the engine exhaust. We must therefore conclude that in the open country under normal conditions the dust content of the atmosphere is small above an altitude of 2,000 feet from the surface.

On April 12 the influence of smoke from the city of Detroit is apparent at elevations up to 3,500 feet.

CHARACTER OF THE DUST PARTICLES

Finely divided mineral matter, probably dust taken up from the surface of the ground by the wind, predominates in summer, with occasionally a few spores. These latter were observed at intervals from July 12 to November 21, in 1924, the maximum number being 20 per 1,000 cubic centimeters on August 29. In 1925 they were first observed on June 8. During the winter and especially on mornings with little wind, or with wind from an easterly direction, products of combustion may predominate. These latter are usually larger than surface dust particles.

HIGH MAXIMUM TEMPERATURES IN LATE SPRING OF 1925

By ALFRED J. HENRY

Following the warm winter of 1924–25, especially the month of February, it would not be surprising had there been more or less frequent short periods of unseasonably low temperature and blustery weather in the spring. In Europe such periods did occur, but here in the United States March as a whole was warm. April also was warm and especially characterized by a two-day period of abnormally high temperature when the daily maximum rose to 93° and 94° respectively. The average maximum temperature for April in Washington, D. C., is 63°. Residents of the United States east of the Rocky Mountains, and more especially those who live in Atlantic seaboard States, may recall that once every so often an outburst of summer heat is experienced sometimes as early as April. The April maximum temperature in Washington, D. C., has equaled or exceeded 90° in 5 out of the last 55 years, or 1 year in 11. For May with a mean maximum of 75° the maximum temperature has equaled or exceeded 95° in 6 out of the last 55 years and the highest maximum in that period, 97°, was recorded on May 23 of the present year.

These outbursts are considered as an integral part of the climate of the eastern two-thirds of the United States. They result from an apparently fortuitous combination of at least three basic initial conditions, as follows:

(1) The presence of an anticyclone over the eastern seaboard of the United States, with little or no movement except a slow settling to the southward.

(2) The presence of a cyclone west of the Mississippi, with a slow movement toward the east-northeast.

(3) Small net loss of heat from the earth's surface due to the presence of haze or light cirrus clouds.

When on any day in spring the two items first named are in combination the conditions are ideal for a rapid surface warming over the great interior valleys of the United States. The winds on the west margin of the anticyclone will be southerly, and although they may not necessarily be warm in the beginning they will soon become so. The change to higher temperature is not, as might be expected, uniform and coterminous with the area of the southerly winds, but rather it is localized in certain areas which appear to have a rather definite relation to